Between the Great Rivers: Water in the Heart of the Middle East

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Introduction

Water has been the key natural-resource issue during the three millennia of recorded history in the Middle East. Some regions of the world are drier, and others have higher populations or larger economies, but no other region of the world embraces such a large area, with so many people striving so hard for economic growth on the basis of so little water.

Three dimensions, three crises

This paper describes water stress in the region between the Nile and the Tigris–Euphrates river systems and extending southward to encompass the Arabian Peninsula and the Gulf Islands, a little bigger than what is sometimes called the Mashrek. Reference will be made to a larger group of countries that includes the Maghreb, Libya, Sudan, and Turkey. Throughout this region, the origin of water stress is not limited to scarcity but stems from three interacting crises:

- Demand for fresh water in the region exceeds the naturally occurring, renewable supply.
- Much of the region's limited water is being polluted from growing volumes of human, industrial, and agricultural wastes.
- The same water is desired simultaneously by different sectors in some society or wherever it flows across (or under) an international border.

Water scarcity has been a source of stress since history began, but water quality is a new problem coming to dominate the crisis in many parts of the world. In this region, though, the politics of water is probably of greater concern than anywhere else in the world. Moreover, because these three crises are interdependent, any resolution must deal with all three — quantity, quality, equity — at the same time

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if it is to be economically efficient, ecologically sustainable, and politically acceptable.

Physical and economic sources of stress

For most countries in the Middle East, water is the limiting resource for development (Fig. 1). Iran, Iraq, Lebanon, Sudan, Syria, and Turkey are all fairly well endowed with water; the three Maghreb countries (Morocco, Algeria, and Tunisia), Israel, and Egypt form a middle group; and Jordan, Libya, and countries of the Arabian Peninsula are least well endowed. For Palestinians, the West Bank is relatively well endowed with water resources (Lowi 1993; Lonergan and Brooks 1994). (Much of the water that occurs in the West Bank is today used in Israel.) The Gaza Strip is perennially short of water. However, water availability per capita is decreasing in every country of the region (Fig. 1).

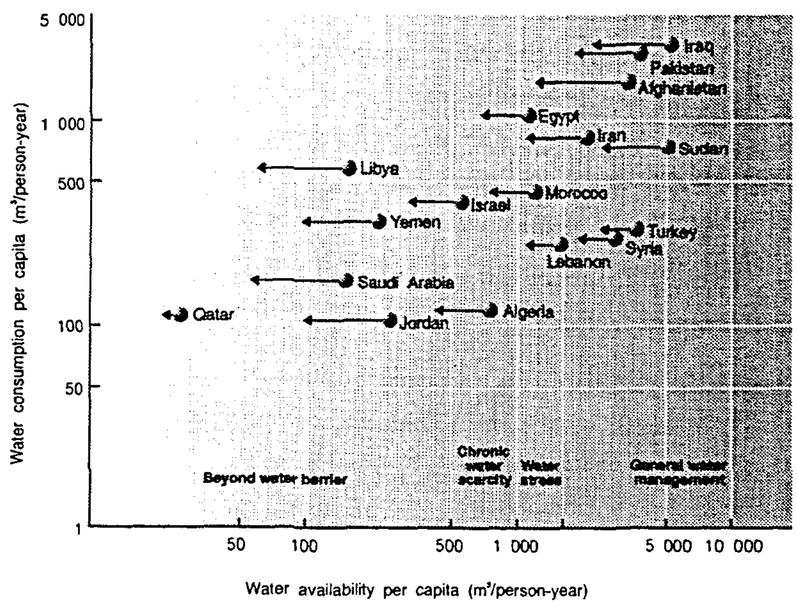


Fig. 1. Water-stress codes for selected Middle Eastern countries (circles depict water stress in 1988; arrows show the changes in per capita water availability by 2020, assuming that per capita consumption stays the same). Source: Falkenmark et al. (1989).

Variation and uncertainty

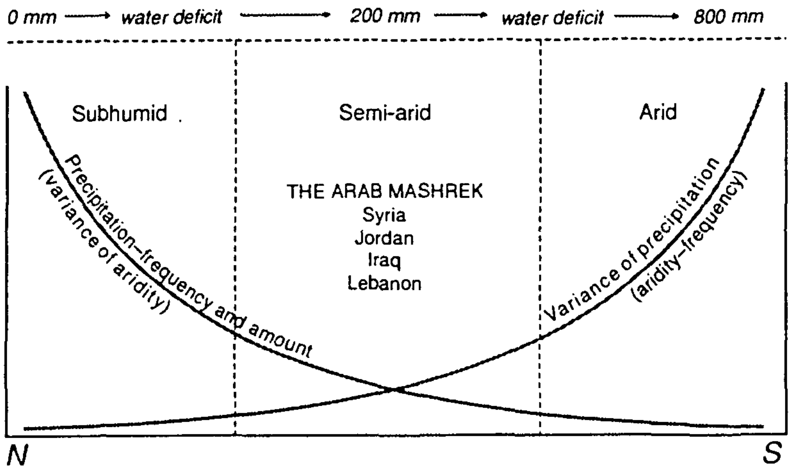
The region between the Nile and the Tigris–Euphrates is highly varied in geography and climate. Coastal plains merge in a few kilometres with mountain ranges, which then plummet to rift valleys with the lowest land elevations on Earth. Rainfall ranges from more than 1 000 mm/year to essentially nil. The average is about 250 mm, which is the limit for unirrigated agriculture, but in this region, averages can be highly misleading. It is much more important to understand the spatial, seasonal, and annual variations in rainfall than national or annual averages.

Bakour and Kolars (1994) showed that the Mashrek lies in a transition zone. To the north, the land receives more rainfall; to the south, even less. The dominant hydrological characteristic is the combination of aridity and uncertainty. Figure 2, taken from their study, compares the two curves: one showing diminishing average rainfall, and the other showing increasing variance (both from north to south across the region). In their words, "the zone of greatest unpredictability is at the intersection of the precipitation and variance curves," that is, in the populated, semi-arid regions of the Middle East. Whereas regions of higher rainfall sometimes suffer droughts and regions of lower rainfall sometimes experience floods, this region has to cope with both.

Even where the variations of rainfall are predictable, sharp transitions bedevil any attempt to use averages. Rainfall along the coast, at the higher elevations of many countries, and in the northern part of the region is more than 500 mm/year, which suggests that irrigation is unnecessary. However, all the rain falls in four winter months, so storage systems are necessary to hold back the flow and permit release during the summer, when demand for water is at its peak. (Unfortunately, large storage systems are generally built as surface reservoirs, which increase evaporation and, thus, decrease still further the volume of water available.)

Variations also occur across short distances. The north end of the Gaza Strip gets rain at upwards of 400 mm/year; barely 50 km to the south, at the border with Egypt, the Gaza Strip gets less than 250 mm/year. The thin coastal strip of Lebanon gets nearly 2.5×10^9 m^3/year; just 50 km to the east, across the Lebanon mountains, the Beka'a Valley, where most of the irrigated agriculture is located, gets only 0.9×10^9 m^3.

The most important variations in rainfall are neither seasonal nor geographic but annual. In eastern North America, reliable flow (defined as what can be expected 9 years out of 10) will be 60–80% of the long-term average; in western North America, reliable flow falls to 30% of the average. In the Middle



GENERAL CHARACTERISTICS

enough water → usually enough land		← enough land never enough water
seasonality (warm/cold)	fluctuations–variability runs of good and bad years extreme seasonality	extreme aridity
drought		floods
low yields per unit area →		← low yields per person
dispersed populations →		← concentrated population
control of land → (traditionally by cavalry)	raiding	← control of water (fortified towns)

TRADITIONAL DEVELOPMENT *(key words: kismet, tradition)*

rainfall agriculture	dry farming/nomadism	hydraulic works
transhumance (conversent up and down mtns)	village/tent symbiosis	qanats/wind towers, etc.

MODERN DEVELOPMENT *(key words: productivity, balance of payments)*

mechanize	settle the nomads/get rid of goats	make the desert bloom
tractors, new seed, monoculture	enclosure, policing, reforestation	deep drilling/ big dams wholesale irrigation desalination, air conditioning

Fig. 2. General characteristics of development in the Arab Mashrek. Source: Bakour and Kolars (1994).

East, reliable flow is less than 10%. These year-to-year variations in rainfall in the Middle East have enormous implications for water systems. In contrast to Europe, Canada, and much of the United States, extreme years in the Middle East must be treated as normal, not abnormal, and water planning and management must focus on risk minimization, not maximum use.

Demography and economy

Most countries in the region are experiencing rapid population growth, with rates of 2.5% per year. Although population densities are not particularly high by world standards, density per hectare of agricultural land is another story. Bahrain has a remarkable 7 000 people per arable hectare; Egypt and Kuwait have close to 2 000; and the other Gulf States, Israel, Jordan, and Lebanon, have more than 500 (Rogers 1994). In the United States, the ratio is less than 2. Other sources of stress come from rapid urbanization (which increases the demand for high-quality water, without diminishing the demand for irrigation water), and the booming economic growth.

Demographic and economic sources of stress are common to many regions of the world. What makes a difference in this region is the dominance of agricultural uses of water, mainly irrigation. Even in relatively urbanized Lebanon, irrigation takes close to 80% of total water. Every country provides water to farmers at moderately to heavily subsidized prices. Although not all water withdrawn for irrigation is actually consumed, the proportion that is returned to a watercourse and the extent of degradation in the natural recycling remain controversial (Moore and Seckle 1993). In Egypt, a great deal is returned with relatively little degradation, but it is dangerous to generalize from the Nile (Allen 1994).

In contrast to agriculture's dominance of regional-water accounts is its decline in economic accounts. Agriculture represents less than 5% of gross national product (GNP) in Israel and Turkey and less than 10% in Jordan and Lebanon. Agriculture represents about 20% of GNP in Egypt and Iraq, and a little more in Syria and the West Bank. Only in Ethiopia, the Gaza Strip, and Sudan does the share approach 40% of GNP. In most countries, the share of employment in agriculture is higher than agriculture's share of GNP, but in Israel and Lebanon, with their capital-intensive farming, the share of employment is lower. With such disproportionate use of water in one sector, and a declining sector at that, political sources of stress are bound to occur.

Quantity: the economic crisis

With its limited water resources, the region from the Nile to the Euphrates not surprisingly contains some of the most parsimonious users of water in the world. A Bedouin may get along with as little as 4 or 5 L/person per day for all uses. Only Australian Aborigines seem to use less. What is a surprise is that the same region also contains some of the least parsimonious users of water. The Gulf States rate among the highest per capita users of water in the world.

Almost all the states of the Arabian Peninsula are consuming much more water than their annual renewable water supply, as are Israel, Jordan, and Libya. Egypt, Syria, and Sudan are fast approaching this situation. Indeed, some projections suggest that by 2025 domestic uses (about 100 L/person per day), plus municipal and industrial uses, will require all the freshwater available, leaving none for agriculture, in the countries of the Lower Jordan (Shuval 1992; Assaf et al. 1993). Even if no more water is devoted to agriculture over the next few years, these countries are in trouble: their water use is unsustainable, which implies that their whole economy is unsustainable. Apart from desalination or imports, the only ways to significantly improve the situation are to improve water efficiency in existing uses and to shift water from low-productivity to high-productivity water sectors. The dominance of irrigation means that both efficiency improvements and sectoral shifts must emphasize agriculture.

Principal sources of water

Throughout history, this region has depended on three main sources of water: rivers, aquifers, and imports (through trade in food). Allen (1994) estimated that the quantity of water imported indirectly into the Middle East as food amounted to 50×10^9 m^3, equivalent to one third of the water directly used and about equal to the annual flow of the Nile in Egypt. Of course, the Middle East also exports food, so the net indirect trade in water is smaller.

Rivers are the best-known sources of water, and the rivers in this region include two of the greatest in the world, the Nile and the Euphrates. As well, many short streams or ephemeral wadis occur, typically being fed by springs in the mountains and spilling into the sea. Aquifers of various types are also common. Some are replenished regularly by rainfall and constitute renewable resources; others contain water buried in sediments eons ago and, thus, constitute nonrenewable resources; a few others occur along fracture zones. Over time, as surface sources have become fully committed and as technology has permitted deeper drilling, there has been a shift to groundwater. Even so, only about 10% of the total supply for the region comes from groundwater. However, in Israel and Jordan, the share from groundwater approaches 50%; and in the Arabian

Peninsula, 100% (if desalination is put to one side). Apart from a few cities, no other region is so dependent on aquifers.

Few opportunities remain for further development of major rivers in these countries; on the contrary, if development occurs, it will more likely be in the upstream countries, such as Ethiopia and Turkey, which could reduce flows downstream (Allen 1994; Hillel 1994). Major freshwater aquifers remain to be developed (indeed, to be discovered), but they are either very deep or located far from points of consumption.

Recycling water

Recycled water may well be the fourth conventional source. Today, the use of treated, recycled sewage water is accepted practice in countries, such as Egypt, Israel, Jordan, and Morocco. (In some countries, raw sewage continues to be used, which risks the spread of cholera and other diseases.) Countries in the region that are truly short of water will have shifted largely from fresh to recycled water for irrigating crops early next century. Some recycled water receives only primary treatment, in which case, use should be restricted to nonfood crops, and special care should be taken to protect farm workers. A good part of the water receives secondary treatment, which means that it can be used for crops that are eaten after cooking. Only water that has received tertiary treatment can be used for all crops. The European Economic Community is considering a proposal to embargo crops grown in reclaimed sewage, but this rule should be resisted as a nontariff barrier designed to protect European farmers. If implemented, it would be a severe blow to Middle Eastern agriculture. Tests for heavy metals and other contaminants not eliminated by conventional treatment are reasonable, but not a flat embargo.

Alternative sources of water

There are many other small, but potentially much larger, sources of water. They can be divided into two groups, depending on a pair of criteria that tend to move in parallel: capital requirements and degree of centralization. Of particular interest in the Middle East are the following:

Low-capital–decentralized solutions

- rainwater catchment from roofs and other structures
- rainwater harvesting in fields and in limans
- capture of flood and winter runoff
- desert dams
- aquifer recharge

High-capital–centralized solutions

- desalination of seawater
- desalination of brackish water
- imports of water by tanker, pipeline, or medusa bags
- cloud seeding

Much more attention should be paid to the low-capital–decentralized options than to the high-capital–centralized ones. To a large extent, the former are not only technically proven but typically more cost effective, given the marginal costs of new conventional water supply. Some options, such as rooftop rainwater catchment, produce only small total quantities of water, but it is potable water. Even in areas of low rainfall, such as the Gaza Strip, it is possible to design low-cost systems, with cisterns scaled to families, that will provide for all drinking and cooking needs (5–7 L/person per day) in most years. The greater problem is not designing the systems but convincing people unused to this technique that the stored water is, indeed, potable.

With the exception of cloud seeding, which has been practiced in some countries for years, the remaining systems are generally too expensive for widespread use. A partial exception must be made for brackish-water desalination, which, depending on location and salt content, can be an appropriate option. Imports of water must be considered, if only because in some countries the use of water depends on the importation of energy. For example, about 20% of Jordan's electricity and 12% of Israel's is used for water pumping. Although such a high share may not be typical (both nations must move large volumes of water from lower to higher elevations), these countries are willing to import oil, in one case, and coal, in the other, so that they can pump water. Of the import options available, the Canadian technology of medusa bags (large plastic bags towed behind ocean-going tugs) appears attractive but remains to be proven at full scale. Turkey is the one country in the region that appears to be both willing and able to consider water imports.

Desalinated seawater is, of course, the ultimate, unlimited source, and about two thirds of the world's "desal" capacity is located in this region. However, all technologies use such vast quantities of energy that major use is restricted to those countries with low-cost oil reserves or heavy-oil fractions left after refining. More potential exists for desalination of brackish water containing up to about 5 000 ppm of salts. Relatively small quantities of brackish water have been desalinated in many countries. In its peace treaty with Jordan, Israel committed itself to desalinating the saline springs that it has diverted to the Lower

Jordan, which now makes this water too salty for use by Palestinian and Jordanian farmers.

A few sources do not fit neatly into either of the two groups. For example, there are numerous aquifers that contain 1 000–5 000 ppm of salts — too salty to be potable but acceptable for certain uses. Some of these aquifers are huge, including one that underlies almost the entire Sinai and Negev deserts. Issar (1994) suggested that the area could be developed on the basis of industrial and agricultural uses of saline water. The aquifers contain fossilized water and, therefore, are nonrenewable, but the supplies are so vast that centuries of use is possible at any likely pumping rate.

The submarine springs that occur all along the coast of Lebanon, Israel, and Gaza and maybe farther are another source of unknown potential. The locations are well known to fisherfolk because some fish can be found at the point where the freshwater and seawater mingle, but no one has ever proposed a practical and ecologically safe method for capturing and bringing the water to the shore.

Main uses of water

Except in a few cases where the objective is to preserve natural beauty, water is not desired for its own sake but because it can satisfy human needs. Despite this basic fact, nowhere is the information available on water use as detailed or comprehensive as that on water supply. Worse yet, with some exceptions, the information is based on deliveries of water, not actual use, which means that it is impossible to make accurate measures of efficiency.

Water use can be broadly divided into four categories: household, municipal, industry, and agriculture. (Municipal use refers both to the water delivered to commercial buildings and hotels, mainly for the same purposes as households, and to the generally larger amounts used for municipal gardens, street cleaning, fire fighting, etc.) Household use accounts for 3–20% of the consumption; municipal, 3–10%; industry, 1–10%; and agriculture, 50–90%.

A surprisingly small proportion is required to meet the drinking-water standards defined by the World Health Organization. At 5–7 L/person per day, only about 2×10^6 m^3/year is needed for every 1 million inhabitants, which is not very much. In most parts of the world and, certainly, in this region, major uses do not require water of potable quality. Depending on the potential contact with humans or the possible fouling of equipment, water of moderately to significantly lower quality can be used. In the future, cities may move to dual systems, with a small pipe providing potable water for drinking and cooking and a larger one providing lower quality water for other uses. Unfortunately, in many countries of the region, there is only a single system, and the water delivered meets only the lower standard.

Pricing reform is at the top of the agenda of every economist who has looked at water supply and demand in the region. Studies of water use in the region have found that consumers of water are subsidized and that these subsidies increase water use above what it would be if consumers had to pay the full costs. Despite the differences in supply, most consumers in this arid region pay no more for water than consumers in humid parts of the United States (Rogers 1994). The need for water-pricing reform is reinforced by other factors. First, because the volumes of water needed to sustain life are so small, it does not matter much whether drinking water is subsidized in the interests of equity or public health. Drinking water is not the problem! Second, among all consumers, farmers receive the greatest subsidies, particularly in comparison with value of output. For some crops, the value added by irrigation is less than the average cost of supplying the water. Third, water prices are typically compared with average cost, but, for economic efficiency, consumers should be paying the marginal cost (the cost to get additional water), which is higher yet. Although most other countries also subsidize water consumers, especially farmers, few countries are so short of water as those between the Nile and the Euphrates. Gradual movement toward more economically efficient water-pricing should be possible without major social losses but with definite ecological gains.

Conservation of water

Conservation of water, including both increases in efficiency of existing uses and changing use patterns, has always been a major consideration in the water-short Middle East. (*Efficiency* and *conservation* are commonly used as synonyms, but, more precisely, the former refers to minimizing inputs to achieve a given output, whereas the latter includes changes in the output. Less formally, efficiency deals with how one accomplishes a task, whereas conservation also includes changes in the task.) However, as we learned from deeper analysis of energy use, the fact that a region is short of energy (water) does not imply either that existing uses are efficiently satisfied or that the pattern of use is appropriate. Many factors, including capital barriers, ill-designed policies, inaccessible technology, lack of information, and habits and traditions intervene.

Continuing with the analogy with energy (Stiles, this volume), we can say that private firms and public bodies must begin to look at reductions in the use of water as a source of supply — a very large source, equivalent to but, in many ways, better than new primary sources. In separate analyses of water-rich Canada and water-short Israel, quite comparable proportionate cost-effective savings were identified (Brooks and Peters 1988; Kahana 1991). This does not mean that Canada and Israel are at equivalent levels of water efficiency. Canada uses four and a half times as much water per capita as Israel. However, because water prices are so much lower in Canada than in Israel, the potential gains in economic efficiency are similar. Without changing use patterns but relying only on off-the-shelf technologies, savings typically exceed 25% and, in some cases, reach 50%. In just 2 years, the city of Jerusalem cut its municipal water use by 14%. These results suggest that the largest potential source of water for most countries in the region will be found through savings achieved by conservation.

Although none of the countries under study comes close to maximizing economic, much less technical, potentials of efficiency in using water, the dominance of irrigation requires special attention. Israel is generally regarded as a model of efficiency in irrigation. Israel pioneered the development of drip irrigation and has gone on to improve the technique with sensors and computer controls that respond to plant requirements, rather than using a predetermined watering schedule. Today, water use per irrigated hectare is 40% less than it was in 1955, and gains continue to be made, although at a declining rate (Kahana 1991; Hillel 1994). Drip irrigation also reduces the likelihood of both salinization and pollution from runoff. Other nations in the region, notably Jordan, have adapted drip irrigation for many crops and are now producing their own pipes and other equipment. Unfortunately, drip irrigation is a capital-intensive technology, and it is not appropriate for all crops.

The greater question about Israeli agriculture and, by extension, all agriculture in the region is not, however, whether water is used efficiently in irrigation but whether irrigation is an efficient use of water. Almost every analysis shows that Israel's economy would be stronger and the total value of output would be increased if water was transferred from agriculture to industrial or municipal uses (Lonergan and Brooks 1994). The opposite appears to be true in the West Bank and Gaza Strip; those economies would be stronger if water could be transferred into agriculture. Careful analysis would be needed to say whether other countries in the region lie closer to the Israeli or to the Palestinian case.

In conclusion, the social gains from approaching water problems from the demand side are very high and not restricted to direct financial savings. Reducing demand is also a very effective strategy (perhaps the most effective strategy) to minimize risk and to reduce environmental damage. The demand approach suggests that in most countries of the region, some water could be transferred from agriculture to other sectors, with overall gains for the standard of living and, very possibly, for the quality of life. The implication is that the long-term demand for water is much more elastic to price and policy than is recognized. In contrast, some analysts believe that water-short areas, such as the Jordan Valley countries, will have no alternative but to turn to external sources by early in the next century (Assaf et al. 1993). These analysts argue that even a higher level of end-use efficiency and a total shift of freshwater out of agriculture would be insufficient.

Water quality: the ecological crisis

Water quality, the second component of the regional water crisis, is less ancient but equally pressing. In the spring of 1994, five nations (Bahrain, Jordan, Lebanon, Syria, and the United Arab Emirates) participated in an environmental conference organized by the American University of Beirut, and each of them identified water pollution as a critical issue. The key point is that — again by analogy to energy — it is just as important to conserve the quality of water as to conserve its quantity (Brooks 1994; Lonergan and Brooks 1994). According to Assaf et al. (1993), Israel is losing 3–10 × 10^6 m^3/year of drinking water because of declining water quality.

Most water-quality problems derive from one or more of four factors: overpumping of aquifers, runoff from agriculture, discharge of human and industrial wastewater, and loss of habitat.

Overpumping of aquifers

Overpumping of wells causes a decline in the water table. During the recent drought, when aquifers were pumped particularly hard, water levels in Israel were falling typically by 10–40 cm/year. Unfortunately, overpumping, or "mining," of what should be renewable aquifers is all too common in this region.

A decline in the water table has several adverse effects. At a minimum, it adds to pumping costs and increases energy use. More important, a lower water table permits lower quality water to flow inward and contaminate the freshwater of the aquifer. Many of the countries in the region have coastal aquifers that, in their natural state, are 3–5 m above sea level; this, in turn, creates an outward pressure that blocks the inflow of seawater. Pumping, or, more accurately, overpumping, has lowered the freshwater level to below sea level, so the effect is reversed and salt water from the Mediterranean can now be found 1–3 km inland.

Runoff from agriculture

Irrigation is obviously good for farmers (MacLean and Voss, this volume). However, irrigation systems also pose environmental problems. In most countries in the region, agricultural runoff is the major non-point source of pollutants, including sediment, phosphorous, nitrogen, and pesticides. Per-hectare use of pesticides and fertilizers in Israel, Jordan, and Palestine rates among the highest in the world, and runoff is correspondingly high. One result of this is that over the past two decades, nitrate (from both fertilizers and reused sewage effluent) concentrations in the coastal aquifer underlying Israel and the Gaza Strip have doubled (Gabbay 1992). In Syria, Al-Sin Lake, the main freshwater source, is polluted by runoff. Such problems are anything but inevitable. Practices like conservation tillage, contour planting, terracing, and the use of filter systems can control soil erosion and reduce phosphorous and nitrogen runoff by up to 60% (World Resources Institute 1992).

Problems are magnified at the greenhouses and poultry factories, which are increasingly widespread in the region. Greenhouses are periodically rinsed, with as much as half of the chemicals going directly into the soil. Good practice isolates these operations from contact with groundwater and recycles the rinse water, but good practice is uncommon. In addition, the otherwise attractive use of brackish water for irrigation can increase soil salinity. Washing out the salts with freshwater can alleviate local problems, but this would allow the salts to drain into watercourses or aquifers, with potential long-term problems. For this reason, irrigation with brackish water is subject to special regulations where it is done just above sensitive parts of the coastal aquifer in Israel.

Discharge of human and industrial wastewater

Cities in this region are old — in some cases, ancient — and, just as with many newer cities, water-supply and sewer systems have either begun to deteriorate or cannot handle the growing loads placed on them. For example, the city of Jerusalem still discharges half its wastewater untreated into dry riverbeds. (A treatment plant is now being built.) In some cases, systems have been damaged by war. Water losses in Beirut went up from 40% to well over 60% during the 15 years of civil strife, and many sewage-treatment plans are inoperable because of shelling. Generally, however, urban areas in the region have adequate systems. In contrast, the situation is far from adequate in smaller cities and rural areas. In a few cases, as in much of the Gaza Strip, the need for investment in water-supply, drainage, and sanitation facilities is immediate.

It is difficult to assess the extent of industrial contamination in the region because so few tests are done, and when tests are done, the results are seldom disclosed. Spot checks by the Ministry of the Environment in Israel have found concentrations of specific contaminants at levels that are a few to 100 times the levels allowable in European countries. Conditions elsewhere are unlikely to be any better. Throughout the region, dumping of industrial wastes is common, sometimes directly into watercourses and sometimes into wadis, which, at the next rainfall, allows contaminants to seep into aquifers. Cleaning a polluted river is difficult; cleaning a polluted aquifer is much more so, and in some cases is simply not possible (Goldenberg and Melloul 1992). Even agricultural processing has its problems. Olive-oil mills, an otherwise excellent innovation that increases the value added from farming and provides employment in rural areas, produce both solid and liquid residues. The solid residues can be put back on fields, but the liquid residues have so high a biochemical oxygen demand that they are generally just dumped. The impact of about 40 mills in Jordan is equal to that of a city of 1 million people.

Loss of habitat

Finally, water quality in the region is being seriously degraded by losses of natural habitat, mainly wetlands. As a result of decisions to drain swamps, canalize rivers, or expand the agricultural frontier, water that was providing habitat for a multitude of plant and animal species is lost. Dredging and reclamation of land to expand urban space in Bahrain has not only destroyed commercial fishing grounds but also blocked natural drainage of agricultural land and increased the salinity of groundwater.

Why are these losses important? It is because water in place and the habitats it supports have value. Some of the values of in situ water, such as those associated with fisheries and hydropower or even with the prevention of subsidence above an aquifer, can be measured in conventional economic terms. Other values are partially calculable, such as those associated with recreation and tourism or with the dilution or purification of wastes. Some values are extremely difficult to capture in economic terms, like those associated with the regulation of river flows or the support of plant and animal habitat.

Losses in the region resulting from uncontrolled use of wetlands are unknown but clearly high. For example, the King Talal reservoir is too polluted for recreational use, but, as the only standing body of water in Jordan, this pollution carries an extraordinary opportunity cost. Wetland conversion can also be controversial. Construction of the Jonglei scheme to increase water flows to Egypt and Sudan "was stopped in the early 1980s as a result of violent opposition by the local communities who did not want their livelihoods and ways of life changed by the draining of the swamps of the Sudd" (Allen 1994). In the case of the Hula Swamp, the draining of which was Israel's first megaproject, plans are under way to restore part of the drained area to its original ecology.

Water equity: the political crisis

Water, not oil, has historically been at the heart of most political conflicts in the countries in this region. This section considers the internal institutions that have been developed to manage conflicts among sectors; and the international institutions that have been developed to manage conflicts among nations.

Internal institutions

This region is characterized by some of the largest and most sophisticated water-management agencies in the world. By and large, they have achieved the goals set out for them. They manage the water systems within their jurisdiction with great care, and they have developed impressive databases that permit control on a well-by-well or pump-by-pump basis. The real problems lie deeper — one begins to question the goals themselves and the structures erected to achieve these goals.

In every country of the region, water-management institutions are oriented to the goals of supply management (construction of dams, storage reservoirs, and other engineering works), with little attention to demand management. Further, the national institutions typically devote most of their attention to large-scale, centralized forms of supply management. Small-scale, decentralized options tend to be neglected or left to communities. The national institutions tend to be insensitive to indigenous practices, gender concerns, ethnic groups, and the environmental impacts of the institutions' actions. Such organizations merely reflect the concerns of the governments that created them.

Water-management agencies in this region differ only in degree from their counterparts in most other countries, North or South. Their true distinctiveness lies in two other characteristics: the centralization of water management at the national level and their close relationship with national agricultural agencies. Every one of the Middle Eastern countries has a ministry or senior agency in control of water affairs. Lebanon, for example, has the Ministry of Water and Electricity. Jordan has the Ministry of Water and Irrigation. In Israel, the Water Commissioner, a powerful official who controls planning, construction, and management of the nation's water system, reports to the even more powerful Minister of Agriculture. The situation is mixed in Syria and Egypt, where central agencies maintain control over irrigation water, and domestic water supply is left to local or municipal agencies.

The close political association of water and agriculture means that intersectoral conflicts tend either to be ignored or to be resolved in favour of farmers. It also means that internal water institutions resist suggestions to increase water prices for farmers or to move toward any form of water market or other means of establishing rational allocation. (There are many policy choices between volume allocation and pure markets that can provide for efficiency and equity.) As a result of the use of nonmarket prices in the face of limited water supplies, central control is required to impose allocations by volume or time of use; in rural areas, like those along the upper Nile, traditional patterns of allocation may still hold. Outside agriculture, prices are less closely controlled, and there is less need for allocation. In many countries (notably, Iraq, Jordan, Libya, Syria, and Yemen), demand is supply limited because of the infrastructure being unreliable or undersized or because of the poor quality of the water, particularly in the summer.

An exception to the bias in favour of agriculture occurs in times of drought. When water-supply allocations must be cut back, farmers typically bear the brunt of cutbacks. No sector can reduce water use so extensively and so quickly as agriculture.

International institutions

Surface water commonly crosses or forms an international border; aquifers commonly underlie a border. For a somewhat larger part of the Middle East, Rogers (1994) counted 25 international rivers. I know of no comparable tabulation for aquifers, but two examples are the Disi Aquifer, which underlies the border of Jordan and Saudi Arabia, and the Mountain (Yarkon–Taninim) Aquifer, which underlies Israel and Palestine. The Litani, in Lebanon, is one of the few rivers carrying more than 500×10^6 m^3/year that does not cross an international border.

International water is almost everywhere a subject of intense debate, with the discussion dominated by international lawyers and diplomats, rather than by social or physical scientists. In the Middle East, the basic principle for sharing water remains that of equitable use. This implies that the ways specific bodies of water are shared must be negotiated to fit the physical, economic, and social context of the parties involved. The rights of parties to specific quantities and qualities of water remain a contentious issue. In these circumstances, it might be helpful to shift attention from rights aimed at the supply side to rights to guarantee certain levels of demand. This is the effect of an approach supported by an Israeli–Palestinian team (Assaf et al. 1993), who proposed entitlements of 125 m^3 of potable water per person per year (Shuval 1992).

Although international law applies most directly to surface water, each of the principles used in dealing with surface water applies to underground water, qualified of course by the limited knowledge of aquifer hydraulics and the greater difficulty of monitoring. A model treaty for internationally shared aquifers has been drafted (Hayton and Utton 1989), but it has not yet been extensively discussed by politicians.

Discussions about international waters, including those in the Middle East, typically conclude with a call for basin-wide or aquifer-wide commissions to manage them as a unit. In my view, such schemes are visionary or, at best, premature. There is simply too little trust among these nations to consider joint management. It has taken the United States and Canada many years to establish joint procedures for management of the St. Lawrence River and almost as long for the Netherlands and Belgium to learn how to manage the aquifer that underlies their border.

This go-slow approach toward international management is not intended to preclude cooperation by way of prior notification of changes in river regime or specific joint institutions, such as those for research. Nor does it exclude the possibility of true joint management in those cases, such as the Mountain Aquifer, where Israelis and Palestinians really have no other alternative (Feitelson and Haddad 1994). Even in these cases, step-by-step movement toward cooperation with parallel but not united institutions on either side of the border would probably be more successful than attempts to move quickly to regional institutions.

Although joint management seems premature for quantity issues, it may not be so for quality issues. Competing demands for water rights have something of a zero-sum aspect about them, whereas environmental problems can affect all parties together. Nations that share water resources, particularly aquifers, should therefore experiment, at first, with joint water-quality management.

Militarization of water

Over the years, many people have argued that a war over water in the Middle East is more or less likely (most recently, Bulloch and Darwish 1993). It is true that, at times, shots have been fired and bombs dropped on water installations. Skirmishes were occurring between Israel and its neighbours just prior to the 1967 war, and Israel bombed a partially completed dam on the Yarmouk, late in that war. Iraq destroyed much of Kuwait's water-desalination capacity during the Gulf War. However, to go from these examples to a general proposition of water wars ignores the wide range of options available for overcoming water scarcity, such as drip irrigation and shifts to crops that consume less water. Such approaches can relieve the pressure much less expensively and with much less risk than military conflict.

Consider what is presumably the point of greatest dispute: the Jordan Valley. Even here, where the allocation of water is anything but equitable, water problems stem as much from internal economic decisions as from the special conditions of military occupation (Elmussa 1993). Using a different approach, researchers in the Harvard Middle East Water Project have reached the same conclusion. Depending on the particular resolution of the property rights to water, the total value of water in dispute between Israelis and Palestinians cannot exceed $600 million CAD per year (in 1996, 1.36 Canadian dollars [CAD] = 1 United States dollar [USD]) and probably lies closer to $200 million CAD. This is not very much money in international terms. The annual cost of water loss appears to be well under the daily cost of modern warfare.

If water wars in the Jordan Valley are unlikely, one wonders whether they will occur anywhere. There are simply better alternatives than war. However, these may not be politically easy or free of conflict. "Water shortages will aggravate tensions and unrest within societies," but, as opposed to outright warfare, "internal civil disorder, changes in regimes, political radicalization and instability" are the more likely consequences (Homer-Dixon et al. 1993).

Research as part of the solution

Research priorities should cover three categories: technical, socio- and enviro-economic, and institutional. The following are the most pressing research gaps.

Technical studies

1. Agricultural techniques appropriate for water scarcity:
   - use of poor-quality or saline water;
   - degree of natural recycling under different conditions; and
   - long-term effects of recycling irrigation water and treated wastewater.
2. Aquifer hydraulics and potentials:
   - discontinuous or karstic formations; and
   - fossil aquifers.
3. Alternative sources of supply:
   - rooftop harvesting for drinking water; and
   - rainwater harvesting and savanization for improved ecological conditions and farming.
4. Existing and alternative strategies in agriculture and industry for times of water stress.

Socioeconomic and enviroeconomic studies

1. Application of "soft energy" approaches to water to determine how far the analogy can be pursued and whether comparable policies could be proposed.

2. Careful estimation of the elasticity of long-term water demand to combinations of price, income, and policy change.

3. Better definition of noncommercial services, such as recreation; of environmental services, such as habitat preservation; and of water in situ.

4. Evaluation of market-based options for national or regional water management:

   - efficiency and equity effects of marginal-cost pricing and other pricing structures on various sectors, ecosystems, and classes;

   - efficiency and equity effects of alternative quasi-market allocation techniques;

   - methods for adjusting pricing for different qualities of water supply and of wastewater runoff; and

   - approaches based on international trading at nationally determined prices (such as the Harvard Middle East water model).

5. Review of traditional methods of augmenting water supply and limiting water demand to see how they compare (in efficiency, equity, and gender effects) with modern methods.

6. Evaluation, using various criteria, of the range of megaproject and regional import options for major increments of water supply, to develop a preferred ranking under various conditions.

Institutional studies

1. Better identification of the barriers to the adoption of, or investment in, water-saving technologies; and design of policies to lower those barriers.

2. Comparison of market and nonmarket institutions for distributing water efficiently and equitably.

3. Options for joint or shared management of transboundary water resources, particularly with respect to water quality.

4. Options for community- or common-property management for water.

5. Measures to increase awareness of the need and the means to conserve water.

6. Improved design for water utilities that incorporate

   - water supply and wastewater removal and reuse;

- supply-side and demand-side concerns; and
- economic, ecological, and social issues.

Conclusion

What the Middle East faces is not so much a water crisis as a chronic problem escalating to crisis dimensions because older problems are deepening at the same time as newer ones are becoming evident. With few exceptions, the countries in this region have already reached or are fast approaching the limits of their indigenous water supplies. In the absence of imports, greater efficiency in water use or shifts of water from one sector to another are the only options left, except for those few countries with enough energy to run desalination plants. Greater efficiency in water use may be encouraged by the existing institutions; shifts of water from one sector to another are almost never encouraged by the existing institutions.

Water is the consummate political issue in the Middle East. The role of research should be to ensure that economically efficient, ecologically sustainable, and politically acceptable alternatives are developed and put forward forcefully enough to lead to both the necessary internal adjustments and the equally necessary international negotiations. In the absence of political movement, water could, indeed, be a destabilizing or disruptive element in national and international relations.

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